A NEW CONSTRUCTION OF A MOBILE COMBINE DRYER

Prof. Geramitchioski T. PhD.[1], Prof. Mitrevski V. PhD.[1], Doc.Vilos I. PhD.[1] PhD.[1], Doc.Trajcevski Lj.
Faculty of Technical Science – University St. Kliment Ohridski Bitola, Republic of Macedonia [1]

Abstract: *In this paper the construction of mobile combine solar – biomass dryer for drying of vegetables and fruits was presented. The dryers was designed for small producers of agriculture products in rural areas. The development and the application of the science designing led to the use of the methodical construction where the designing direction is carried out into phases and present an act of solving all constructive assignments.*

Keywords: combine dryer, construction, vegetable, fruit.

1. Introduction

Fruits and vegetables are agricultural products that are known for their rich vitamins, high concentration of moisture and low fats. They are highly perishable due to excess moisture present in them especially at harvest. Fruits and vegetables are seasonal crops and are mostly available during the production season.

Drying of produce especially vegetables and fruits is one of the oldest forms of food preservation methods known to man. It is the removal of moisture from the product to an optimum level in order to prevent deterioration and preserve their nutritive values.

In rural areas, drying is accomplished by direct exposure to the sun because it is relatively easy. However it is dependent on weather conditions and is susceptible to contamination.

One significant limitation of solar dryer is that can only be used during the daytime when there is adequate solar radiation. For commercial producers, the ability to process continuously with reliability is important to satisfy their markets. Therefore, it is necessary to provide solar dryer with additional source of energy.

In this paper the construction of mobile combine solar – biomass dryer for drying of vegetables and fruits with capacity that is suitable for use in single farm and small cooperatives.

2. DESIGN OF HYBRID DRYER

This cabinet type dryer has three main components: (1) drying chamber, (2) solar collector, and (3) biomass gasifier stove. The drying chamber has 30 aluminium wire screen trays that hold the products in place during drying. A polyethylene plastic screen, which is much cheaper, can also be used as an alternative to the aluminium tray material. The capacity of the dryer depends on the type of fruit to be dried. For pineapple, the dryer has a maximum capacity of 50-kg sliced fruit per batch. There are two sources of heat available for the dryer: solar collector and biomass gasifier stove.

Solar Collector

The collector, which is a flat plate type, hasan air collection gap of 5 cm and an insulation of about 8 cm thick. The absorbing surface, which receives insolation, is a matte black painted metal sheet. A single Plexiglas cover with a thickness of 1/8” was positioned above the absorber. This is attached at the backside of the drying chamber at an angle of 15°. The fan inside the chamber forces the ambient air to pass through the collector and rise up to the fruits being dried.

Biomass Gasifier Stove

The biomass gasifier stove on the other hand is provided to assist in the drying operation whenever solar insolation is insufficient and unavailable. This is composed of four main components: fuel storage hopper, reaction chamber, primary air inlet and combustion chamber. The hopper is positioned vertically on top of the reactor where producer gas is produced. An ash collector is provided at the bottom of the reaction chamber. A primary air inlet is attached at one side of the reactor, which supplies air to the chamber. On the opposite side is the combustion chamber where the gas produced in the reactor is burned and flue gas is generated. A sliding plate is provided at the bottom of the combustion chamber for the supply of secondary air needed for combustion. The gasifier stove consumes about 2.0 kg per hour of wood or 4.0 kg per wood briquette, and can provide a drying air temperature of up to 60°C. The temperature can be controlled through a sliding plate provided in the duct that connects the chamber and the furnace. Other specification of the fruit dryer is shown in the table below.

Table 1. Dryer Specifications o

Capacity per batch 50-kg sliced fruit or vegetables

Dryer dimension 140 x 100 x 269 cm

Number of trays 30

Tray dimension 98 x 50 cm

Tray material Aluminum wire screen/

Polyethylene plastic screen

Fan airflow rate 0.16 m3/s

Fan diameter 30.48 cm

Solar collector area 212 x 90 cm

Collector air gap 5 cm

Fuel of furnace Coconut shell/ charcoal

Biomass bruner was only used at night, while solar energy, or combination with stored heats were used during the daytime.

The design of the biomass system was based on the following considerations:

- the heating will be indirect, i.e. flue gas from the biomass stove and the drying air would not be mixed. This will protect the product being dried from contamination by the smoke, soot and ash of the flue gas
- the temperature of inlet air would be in the range of 60-70 oC. This is based on the allowable maximum drying temperature for most of fruits and vegetables
- temperature control of the drying air would be possible, by controlling the combustion in the stove, by opening or closing the primary air supply in the stove
- biomass operation could carried out for extended periods of times, unattended. The stove was designed to operate continuously for about two our for a single fuel loading with wood or wood wood briquette.

The whole design and construction of the combined dryer with solar and bio-mass energy sources is given on Fig.1 . On fig.2 is given the cross-section view of the combined solar dryer.

RESULTS AND DISCUSSION

Apple is an important agricultural food product used in food industry. In Macedonia apple is used locally, and is also exported. Apples are dried at a temperature of 60÷70 ^{o}C, to a final moisture content of 20 ^{o}C.

The amount of moisture content removed from a wet material is

$$m_w = m_1 \frac{(d_2 - d_1)}{(100 - d_2)} = 20 \frac{(88-20)}{(100-88)} = 17 \text{ kgH}_2\text{O}$$

where is m_1 = 20 kg initial mass of dried material, d_1 = 85 % and d_2 = 20 % are initial and final moisture content of dried apples.

Average drying rate for 8 sunshine hours (from April to August) is

$$m_{dr} = \frac{m_w}{\tau} = \frac{17}{8} = 2.125 \frac{\text{kgH}_2\text{O}}{\text{h}}$$

The mass flow rate of air can be calculated by

$$m_a = \frac{m_{dr}}{(x_f - x_i)} = \frac{2.125}{(0.0272 - 0.0216)} = 379.46 \frac{\text{kg}}{\text{h}}$$

Using psychometric principles, ambient air is heated from (temperature t_a = 30 ^{o}C, relative hymidity φ_a = 80%) to (t_p = 40 ^{o}C, φ = 47%) at a constant humidity ratio. The heated air passes through the drying bed and picks up moisture from fresh apples at constant enthalpy, increasing initial humidity ratio x_i = 0.0216 kg H2O/kg dry air to x_f = 0.0272 kg H20/kg dry air, where it is assumed saturated at t_a = 32 ^{o}C and φ_a = 90% above drying bed.

The initial and final enthalpy of moist air is

$$h_i = 1.006 t_a + x_i (2500 + 1.86 t_a) = 85.38 \text{ kJ/kg dry air}$$

$$h_f = 1.006 t_f + x_f (2500 + 1.86 t_f) = 101.81 \text{ kJ/kg dry air}$$

Total heat energy required to evaporate the water is

$$E = m_a (i_f - i_i)\tau = 379.46(101.81 - 85.38)8 = 43.51 \, MJ$$

The dimension of collector surface area for incident solar radiation for Macedonia I = 15 MJ/m^2 day and collector efficiency η = 0.3 (0.3÷0.5) is

$$A = \frac{E}{I\eta} = \frac{43.51}{150.3} = 5.802 \text{ m}^2 = 6 \text{ m}^2$$

The volumetric air flow rate is

$$V_a = \frac{m_a}{\rho_a} = \frac{379.46}{1.28} = 296.46 \frac{\text{m}^3}{\text{h}}$$

where ρa = 1.28 kg/m3 is density of dry air.

In case of low solar irradiation during the day, the drying process can be backed up by a biomass heater.

CONCLUSION

With the development of the fruit dryer, the farmers of the Republic of Macedonia are now able to utilize their fist-sized apple fruits. For them on the other hand, drying will not only extends the shelf life of their apples and other fruit crops but will also increase its value.

The fruit dryer were designed based on the following criteria:

(1) the area has a considerable production of fruit crops,

(2) availability of biomass resources within the site and neighbouring areas, and

(3) client's drying needs.

A combine solar-biomass dryer was designed and constructed based on preliminary investigations of fruits drying under controlled conditions (laboratory dryer).

REFERENCES

[1] T.Geramitcioski, V.Mitrevski, *Design and construction of a mobile solar dryer*, Second International Conference Sustainable Postharvest and Food Technologies INOPTEP 2011, Velika Plana, 17-20 April, 2011

[2] A. R..Elepaño, K.T. Satairapan, *A SOLAR-BIOMASS DRYER FOR PINEAPPLEA* , 51st Philippine Society of Agricultural Engineers National Convention held in Cebu Plaza Hotel, Cebu City, 23 to 27 April 2001.

[3] A. R..Elepaño, K.T. Satairapan, *Renewable energy-based fruit dryers*, Manufacturer's Forum held in the Institute of Agricultural Engineering, College of Engineering and Agro-Industrial Technology, University of the Philippines Los Baños last 27 May 2002

[4] El-Shiatry, M.A. Muller, J., Muhlbauer, W. (1991). Drying fruits and vegetables with solar energy in Egypt. AMA, 22(4), 61-64.

[5] Hernandez, J. A., Pavon, G., Garcia, M.A. (2000). Analytical solution of mass transfer equation considering shrinkage for modeling food-drying kinetics. Journal of food engineering, 45(1), 1-10.

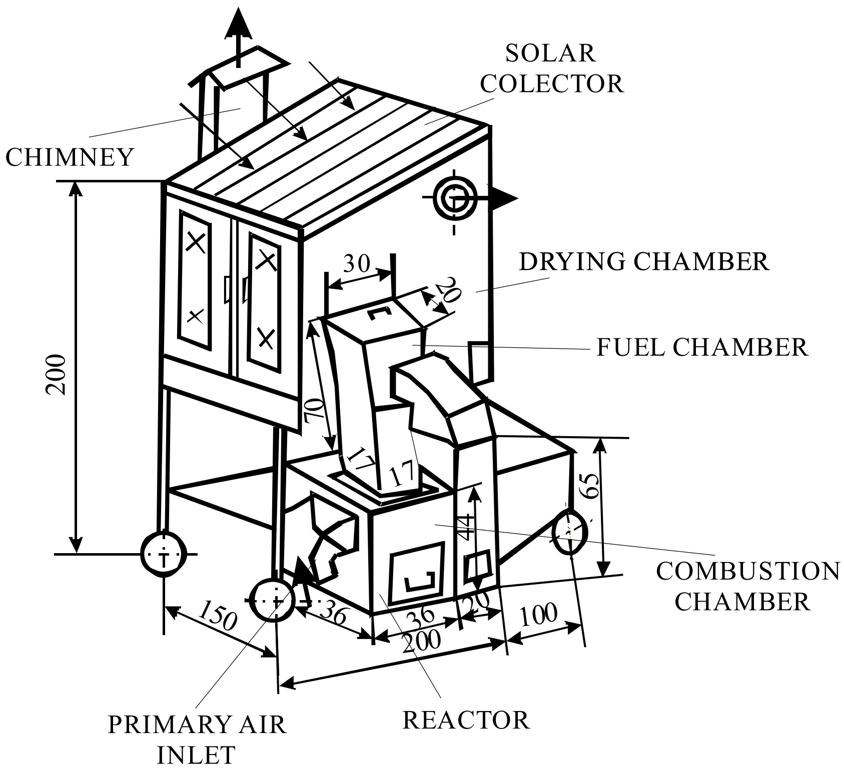

Fig.1. Combined solar and bio-mass energy sources dryer

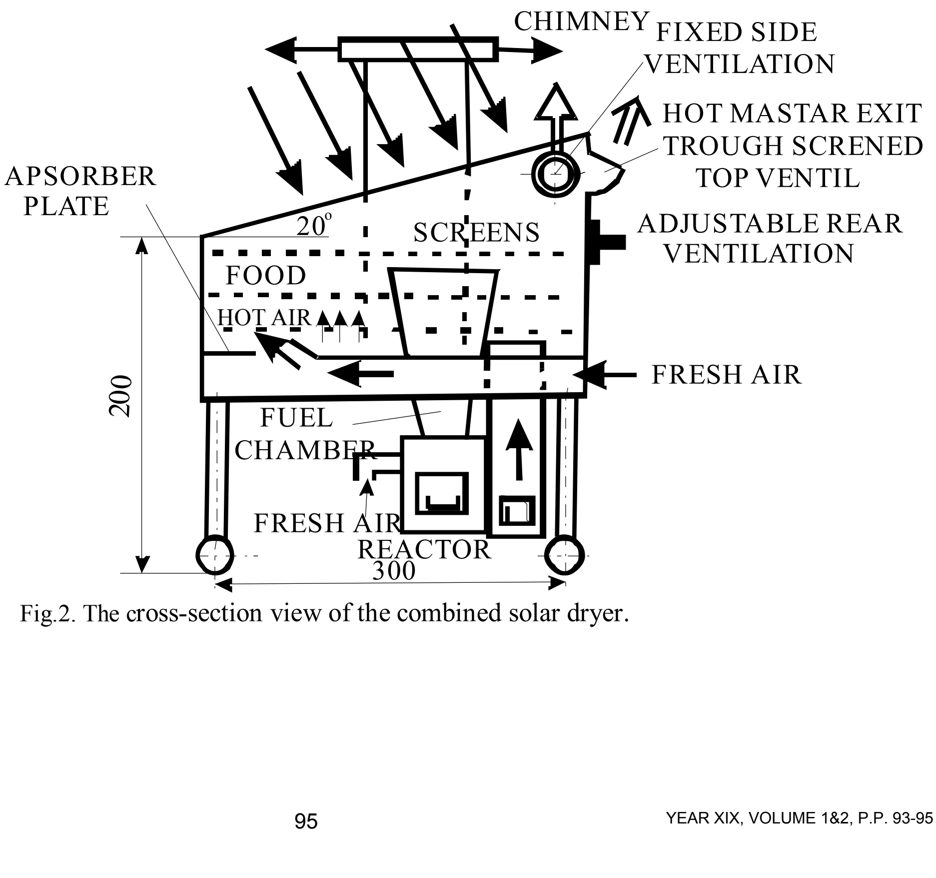

Fig.2. The cross-section view of the combined solar dryer.